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# A proposal of a new model for long-term weaning: Respiratory intensive care unit and weaning center

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Received 31 January 2010; accepted 16 May 2010

Available online 11 June 2010

## KEYWORDS

Mechanical ventilation;  
Intensive care;  
Pulmonary  
rehabilitation;  
Prolonged weaning;  
Respiratory failure

## Summary

**Background:** Respiratory intermediate care units (RICU) are hospital locations to treat acute and acute on chronic respiratory failure. Dedicated weaning centers (WC) are facilities for long-term weaning.

**Aim:** We propose and describe the initial results of a long-term weaning model consisting of sequential activity of a RICU and a WC.

**Methods:** We retrospectively analysed characteristics and outcome of tracheostomised difficult-to-wean patients admitted to a RICU and, when necessary, to a dedicated WC along a 18-month period.

**Results:** Since February 2008 to November 2009, 49 tracheostomised difficult-to-wean patients were transferred from ICUs to a University-Hospital RICU after a mean ICU length of stay (LOS) of  $32.6 \pm 26.6$  days. The weaning success rate in RICU was 67.3% with a mean LOS of  $16.6 \pm 10.9$  days. Five patients (10.2%) died either in the RICU or after being transferred to ICU, 10 (20.4%) failed weaning and were transferred to a dedicated WC where 6 of them (60%) were weaned. One of these patients was discharged from WC needing invasive mechanical ventilation for less than 12 h, 2 died in the WC, 1 was transferred to a ICU. The overall weaning success rate of the model was 79.6%, with 16.3% and 4.8% in-hospital and 3-month mortality respectively. The model resulted in an overall  $39\,845 \pm 22\,578$  € mean cost saving per patient compared to ICU.

**Conclusion:** The sequential activity of a RICU and a WC resulted in additive weaning success rate of difficult-to-wean patients. The cost-benefit ratio of the program warrants prospective investigations.

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## Introduction

Patients with acute (ARF) and acute on chronic respiratory failure (ACRF) may require intensive care unit (ICU) admission for ventilatory assistance.<sup>1</sup> Most of the ACRF patients may be treated with non-invasive ventilation (NIV),<sup>2,3</sup> a reduced proportion of these patients in the ICU need invasive ventilation, and eventually will need prolonged ICU length of stay (LOS) due to difficult weaning.<sup>4,5</sup> ICUs are expensive resources<sup>6</sup> and probably lack the necessary focus, personnel and organisation to care for difficult-to wean patients.<sup>4,7</sup> Recently the problem of appropriate ICUs utilisation has been faced by proposing two type of units<sup>4</sup>:

- 1) "step-up" units like respiratory intermediate care units (RICU) within acute care hospitals manage patients with ARF or ACRF with NIV, resulting in significant reduction in ICU admissions and need of invasive mechanical ventilation,<sup>2,3</sup> with adequate level of assistance. These unit may provide multidisciplinary rehabilitation<sup>8</sup> and serve as a bridge to home-care programs or long-term care facilities.<sup>9</sup> Some of these RICUs may work also as "step down" units for difficult-to wean patients.<sup>10</sup>
- 2) Specialised regional weaning centers (WC), often located within Rehabilitation Hospitals, treat difficult-to wean patients transferred from several acute care hospitals. Dedicated WC offer specialised teams (e.g. nurses, respiratory therapists, nutritionists, psychologists, speech therapists etc.) and also relieve pressure on scarce ICU beds at a lower costs. Variable mortality and weaning success have been reported.<sup>11–13</sup>

No integrated weaning activity between these two types of units has been reported so far. We propose a new model of care for tracheostomised difficult-to wean patients consisting of sequential activity of a University Hospital RICU and a dedicated regional WC. We describe the results of the first 18 months of activity.

## Methods

### Locations

The RICU of University Hospital, Pisa is a 4-bed facility, located inside a 28 bed pulmonary ward within a Cardio-Thoracic Department including a cardio-surgery ICU. It is staffed with a 1:4 nurse to patient ratio, a 24-h on duty doctor (in the night shared with the ward), and a 1:4 respiratory therapist to patient ratio. Our RICU mainly admits patients with ARF or ACRF to provide NIV (step up) and at a less extent, tracheostomised difficult-to wean patients may be transferred from the medical or surgical ICUs of University Hospital, Pisa (step down). It is equipped with monitoring and diagnostic facilities, including bronchoscopy, and emogasanalyser, according to ERS criteria.<sup>9</sup> In our hospital the estimated RICU daily stay cost is 900 € compared with a ICU daily stay cost of 1500 €. RICU activity is reimbursed on a Diseases Related Group (DRG) system basis. The RICU's activity started on February 2008.

The integrated 6-bed WC is located inside a 14 bed pulmonary rehabilitation unit of a Rehabilitation Hospital (Auxilium Vitae), in Volterra, 60 Km far from Pisa, which is a referral rehabilitation and chronic care center for a large geographic area in central Italy (Tuscany). It is staffed with a 1:6 nurse to patient ratio, a 24-hour on duty doctor shared with the pulmonary rehabilitation unit, a 1:6 respiratory therapist to patient ratio. Psychological, speech, nutrition and swallowing services are also available. Difficult-to-wean tracheostomised patients are admitted to the WC, either transferred from the RICU of Pisa or from ICUs of other Tuscany Hospitals to undergo either a program of progressive discontinuation from mechanical ventilation or to be discharged to a home program of long-term ventilatory assistance, if weaning from the ventilator fails. The estimated daily cost of WC stay is 470 €. The WC activity is reimbursed on a per patient basis. WC activity started on 2007, October.

Pulmonologists trained in mechanical ventilation serve as primary physicians in both units which are directed by the same person (NA).

### Patients

All consecutive tracheostomised difficult-to wean patients transferred from medical or surgical ICUs to the RICU of University Hospital, Pisa, since February 2008 to November 2009 were retrospectively evaluated. Difficult-to wean patients, were defined as patients requiring more than 7 days of weaning after the first spontaneous breathing trial (SBT).<sup>4</sup> Data of patients transferred to WC from other Tuscan ICUs in the same period are also reported.

### Weaning techniques

In both units patients undergo weaning protocols either of progressive decreasing levels of pressure support ventilation (PSV) or progressively longer periods of SBT as previously described.<sup>6,12,15,16</sup> Physiotherapy is also performed according to accepted protocols.<sup>17</sup> Decannulation is performed on an individual basis according to criteria described elsewhere.<sup>18</sup>

### Measurements

Age, gender, admission diagnoses, Acute Physiology and Chronic Health Evaluation (APACHE-II) score,<sup>19</sup> chronic comorbidities and previous LOS in the ICU of origin were collected. Clinical outcomes were: 1) weaning and decannulation rate, ventilator dependency 2) RICU/WC, Hospital LOS, 3) location after discharge (home, nursing-home, rehabilitation hospital, acute-care hospital), 4) in-hospital and 3-month mortality. Successful weaning was defined according to the National Association for Medical Direction of Respiratory Care (NAMDR) Consensus Conference as the ability to breathe spontaneously for more than 7 consecutive days.<sup>5</sup>

### Statistics

Data are presented as mean  $\pm$  SD. Continuous variables were compared with the two-tailed unpaired Student's *t*

test (parametric data). Categorical data were compared using the Chi-square test. A  $p$  value  $<0.05$  was considered as statistically significant. Analyses were performed using version 10.0 SPSS statistical software package (SPSS, Inc., Chicago Illinois).

## Results

During the study period, 198 consecutive adult patients were admitted to the RICU of University Hospital, Pisa. One hundred forty nine patients (who are not the object of the study) were admitted for monitoring or NIV treatment of severe ARF or ACRF whereas 49 tracheostomised difficult-to wean patients (the object of the study) were transferred from medical/surgical ICUs of the University Hospital after a mean ICU LOS of  $32.6 \pm 26.6$  days ( $28.0 \pm 29.6$  days since tracheostomy).

### Overall results of the model

The details of outcome of patients undergoing the integrated weaning program are shown in Fig. 1. The overall weaning success rate of the integrated RICU and WC activity was 79.6%, with a overall 16.3% in-hospital mortality (8 out of 49 patients). Two out of 41 patients (4.8%) died within 3 month since discharge. Demographic, clinical, physiological characteristics and LOS of difficult-to wean patients according to weaning success or failure, are shown in Table 1. Only arterial carbon dioxide tension ( $\text{PaCO}_2$ ) and clinical severity as assessed by APACHE II score at RICU admission were significantly different between successfully and unsuccessfully weaned patients. Causes of ICU admission were not significantly different between the

two groups. Half of patients unsuccessfully weaned had been admitted to ICU due to post-surgery ARF, whereas all patients admitted to ICU due to acute cardiovascular disease were weaned (Table 2). The overall hospital LOS (including ICUs) of 39 weaned patients of the program was  $52.2 \pm 33.8$  days. On the basis of the reported daily costs of ICUs, RICU and WC, we can estimate an overall  $39\,845 \pm 22\,578$  € mean cost saving per patient, resulting from  $11\,520 \pm 10\,047$  and  $28\,325 \pm 18\,097$  € mean cost saving per patient in RICU and WC respectively for the 10 patients transferred to WC.

### Components of the model

#### RICU

The overall weaning success rate in RICU was 67.3% after  $7.2 \pm 6.1$  days of RICU stay. Twenty-one out of 33 weaned patients (63.7%) were decannulated. As shown in Fig. 1 6 out of 33 weaned patients (18%) were discharged home, 21 (64%) patients were transferred to Volterra rehabilitation unit for a 20 days pulmonary rehabilitation program, 6 (18%) were transferred to other Hospital units due to non respiratory comorbidities. Three patients died in the RICU, 2 more patients were transferred to ICU where they died, 1 patient was discharged home after readmission to ICU. Ten patients (20.4%) failed weaning and were transferred to the dedicated WC after a mean overall  $38.8 \pm 21.8$  days hospital LOS (Fig. 1). The mean cost saving per patient of 39 patients treated only in RICU was  $13\,538 \pm 7435$  €.

#### Weaning center

As shown in Fig. 1 6 out of 10 patients transferred from our RICU (60%) were weaned and discharged either home

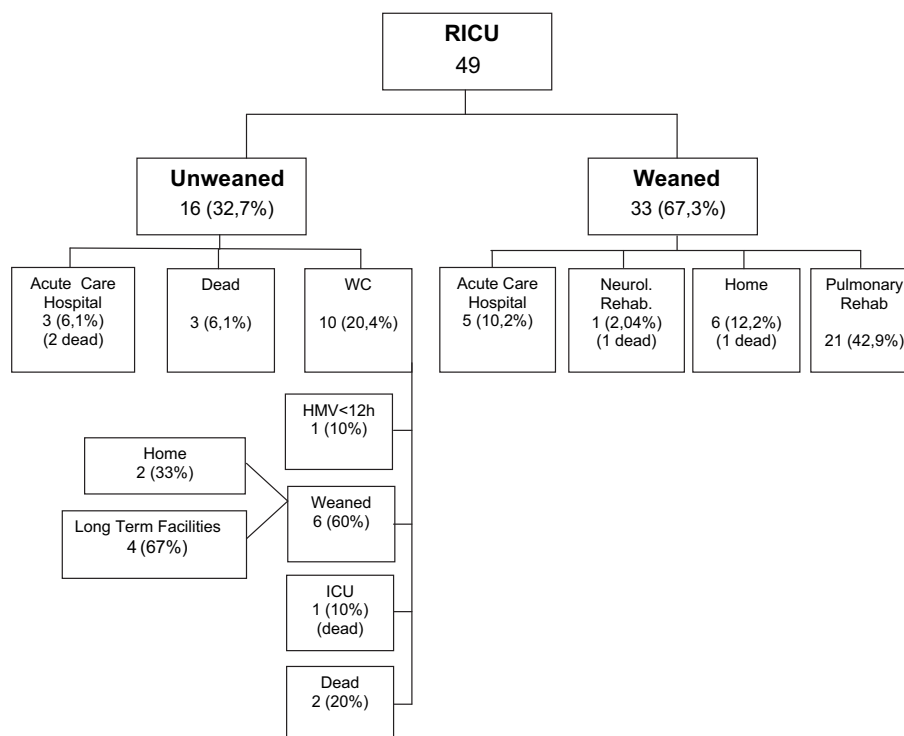


Figure 1 Outcome of patients.

**Table 1** Characteristics and LOS of successfully and unsuccessfully weaned patients in study.

	Total	Weaning Failure	Weaning Success	P
Patient n, female	49, 16	10, 6	39, 10	
Age, years	70 ± 11	74 ± 8	68 ± 12	0.07
Hospital LOS, days	50.5 ± 33.6	63.4 ± 31.2	47.2 ± 33.8	0.58
RICU LOS, days	21.8 ± 13.2	23.7 ± 16.5	16.6 ± 10.9	0.07
ICUs LOS, days	32.6 ± 26.6	39.7 ± 26.7	30.5 ± 26.6	0.26
WC LOS, days		19.7 ± 13.3 <sup>a</sup>	32.7 ± 19.2 <sup>a</sup>	0.07
PaO <sub>2</sub> /FiO <sub>2</sub> admission	247.5 ± 81.5	263.2 ± 130.9	243.5 ± 65.2	0.48
pH admission	7.42 ± 0.08	7.39 ± 0.05	7.42 ± 0.09	0.22
PaCO <sub>2</sub> admission (mmHg)	42.6 ± 12.6	50.5 ± 10.0	40.6 ± 12.5	0.03
APACHE II admission	16 ± 5	20 ± 5	15 ± 4	0.001
Comorbidity (n/patient)	3.2 ± 14	3.7 ± 0.9	3.1 ± 1.5	0.56

P: Statistical significance for difference between Weaning failure and success.

<sup>a</sup> Data refer to 4 unweaned and 6 weaned patients at WC. See Fig. 1.

(2 patients) or to nursing long-term facilities (4 patients) after  $32.7 \pm 19.2$  days. Three out of 6 weaned patients (50%) were decannulated. The total Health Care Units LOS (ICUs + RICU + WC) of these weaned patients was  $59.0 \pm 28.2$  days compared with  $77.2 \pm 29.2$  days of unweaned patients. One out of 10 patients was discharged needing invasive mechanical ventilation for less than 12 h. Two patients died in the WC, one more patient died after being transferred to ICU.

In the same period 144 consecutive difficult-to wean patients were transferred to WC directly from other Tuscan ICUs. The demographic, clinical, physiological characteristics of patients coming from other regional ICUs are shown in Table 3. The causes of ICU admissions are shown in Table 4. The weaning success rate of these 144 patients was 53.5%. Forty-two of the weaned patients (54.5%) were decannulated. Twenty-one (14.6%) of these patients were discharged needing invasive mechanical ventilation for less than 12 h, 19 (13.2%) died in the WC, 5 (3.5%) more patients were transferred to a ICU due to non respiratory complications. As shown in Table 3 the overall LOS in Health Care Units (ICU + WC) was  $78 \pm 41$  and  $89 \pm 59$  days in weaned and unweaned patients respectively.

## Discussion

Prolonged mechanical ventilation has been variously defined.<sup>5,12–14,21</sup> According to the European Respiratory Society (ERS) Task Force difficult-to wean patients of our study, were defined as patients requiring more than 7 days

of weaning after the first SBT (prolonged weaning).<sup>4</sup> These patients have been shown to have a 14% incidence in patients admitted to ICU for intubation and mechanical ventilation and are associated with a in-hospital mortality up to 32%.<sup>20</sup> The report of the NAMDRC Consensus Conference defined prolonged mechanical ventilation as the need for more than 21 consecutive days of mechanical ventilation for more than 6 h a day.<sup>5</sup> Studies have found 3–7% of patients fulfilled this definition.<sup>21</sup> Furthermore patients needing prolonged mechanical ventilation have high resource utilization and relatively poor outcomes, especially the elderly, and are increasing in number.<sup>22</sup> The preliminary results of this report suggest that the sequential activity of units less expensive than ICUs like RICU and dedicated WC has an additive weaning success rate in difficult-to wean patients with substantial costs savings compared with ICU.

## Outcomes

There is great variability in the clinical outcomes of WC in the literature.<sup>4,5,23</sup> Observational studies indicate a 34–60% of successful weaning rate in WC.<sup>24,25</sup> The overall weaning success rate of our model was around 80%, higher than that reported by Polverino et al.<sup>11</sup> in 5 Italian WC belonging to multidisciplinary respiratory rehabilitation units and by Schonhofer et al.<sup>26</sup> The weaning success rate of the 2 individual units of our model was 63.7 and 60% for RICU and WC respectively, values similar to those two studies.<sup>11,26</sup>

The great sample size difference prevents a statistical comparison, nevertheless we can observe the results of the 49 patients of the model and those of 144 patients admitted to Volterra WC directly from other Tuscan ICUs (Tables 1 and 3 respectively). Overall patients were similar as for severity of disease as assessed by APACHE II score, diagnoses of ICU admission (Tables 3 and 4) and comorbidities. Nevertheless the weaning success rate of these 144 patients was 53.5%, similar to 60% weaning success rate of 10 patients transferred to WC, but far less than 79.6 overall weaning success rate of the model. Furthermore the overall total LOS was shorter for patients of the model, with a similar in-hospital mortality (Tables 1 and 3).

**Table 2** Causes of ICU admission of patients transferred to RICU.

Cause of ICU admission n,%	Total (49) n, %	Unweaned (10) n, %	Weaned (39) n, %
COPD exacerbation	13, 26.5	3, 23.1	10, 76.9
Post surgery	12, 24.5	5, 41.6	7, 58.4
Cardiovascular disease	5, 10.2		5, 100
Polytrauma	5, 10.2		5, 100
Other	14, 28.5	2, 14.2	12, 85.7

**Table 3** Characteristics and LOS of WC patients from outside Pisa.

	Total	Unweaned	p	weaned
patients n, female.	144, 54	67, 26		77, 28
Age, years	70.8 ± 11.3	71.0 ± 10.8	0.81	70.6 ± 11.8
APACHE II	14.5 ± 5.6	15.0 ± 5.8	0.24	13.9 ± 5.4
Comorbidities (n/patient)	3.8 ± 1.9	3.91 ± 1.74	0.37	3.88 ± 1.91
arterial pH	7.42 ± 0.05	7.40 ± 0.08	0.80	7.42 ± 0.05
PaO <sub>2</sub> /FiO <sub>2</sub>	226.0 ± 67.3	225.5 ± 65.7	0.94	226.4 ± 66.2
PaCO <sub>2</sub> , mmHg	48.0 ± 13.2	49.9 ± 14.1	0.11	46.2 ± 12.1
pre-wc hospital LOS, days	49.9 ± 41.5	56.4 ± 52.3	0.12	43.8 ± 26.9
Overall Hospital LOS, days	83.7 ± 50.9	89.2 ± 59.5	0.26	78.5 ± 41.0

In this report successful weaning was defined as the ability to breathe spontaneously for more than 7 consecutive days.<sup>5</sup> Proposed definitions of weaning success for these difficult-to wean patients have included 48 h, 7 days, or 14 days without ventilatory support, freedom from ventilator support at the time of hospital discharge,<sup>4,5,12,13</sup> or at 6 months to 1 year after the onset of mechanical ventilation. Such differences in weaning success definition may be related to differences in patient population, discharge criteria, and institution specific characteristics.<sup>5</sup>

Similarly, **hospital mortality** and **LOS** are widely variable.<sup>27</sup> In our model the overall in-hospital mortality was 16.3%, (10.2% in the RICU and 30% of patients transferred to dedicated WC respectively) compared with 23.5% mortality as predicted by APACHE II score.<sup>19</sup> Hospital mortality varies from 50% to 6%, depending on admission criteria, severity of clinical status and underlying diseases and likelihood of transfer to a different facilities when patients become acutely ill.<sup>12–15,20,21</sup>

Pilcher et al.<sup>14</sup> reported the outcome from a specialised weaning programme over 4 years. Of approximately 150 difficult-to wean patients receiving mechanical ventilation for about 20 days before transfer to the unit, 38% were weaned completely from ventilatory support, 35% required home ventilation, and 27% died before leaving hospital. In a US multicenter study at long-term care hospitals<sup>28</sup> on a total of 1,419 difficult-to wean patients, 54.1% were weaned. Median time to wean was 15 days. Better outcomes were reported in a previous Italian study in COPD patients.<sup>12</sup> However comparison between studies of different centers and different periods may be not appropriate, as weaning success seems strongly related to patients' complexity and comorbidities,<sup>11</sup> to hospital organisation and personnel expertise,<sup>29</sup> availability of early

physiotherapy,<sup>30,31</sup> use of weaning protocols,<sup>12</sup> patients' autonomy and families' preparation for home discharge with ventilation.<sup>32</sup>

When evaluating outcome it is necessary to consider the severity of patients at admission. The causes of ICU admission of our patients differ somehow from those by other studies,<sup>11</sup> including a relatively reduced proportion of COPD patients and a greater proportion of post –surgery. The severity of our patients is demonstrated by the long previous ICU stay, by mean APACHE II score of 16, and the mean number of comorbidities per patients, higher than those of Polverino et al.<sup>11</sup> but less than those by Tobin et al.<sup>33</sup> At difference from Schonhofer et al.<sup>26</sup> in our study APACHE II at admission was able to differentiate successfully from unsuccessfully weaned patients in the RICU (Table 1).

Most of the weaned patients of our model (61.5%) were decannulated. This result is in agreement with those of Tobin et al.<sup>33</sup> but differs from those by Engoren et al.<sup>34</sup> and from those of a recent survey on 719 patients of 22 Italian RICUs<sup>18</sup> showing that tracheostomy was maintained in a substantial proportion of patients without any need for home mechanical ventilation. The clinical relevance of decannulation at discharge is supported by a recent study who showed that lack of decannulation of conscious tracheostomised patients before ICU discharge to the general ward was associated with higher mortality.<sup>35</sup>

## Weaning protocols

In both units of our model similar weaning protocols<sup>12</sup> are used, namely a strategy of progressive reduction of PSV,<sup>16</sup> or progressively longer periods of SBT. Indeed no significant difference in weaning success and mortality rate, duration of ventilatory assistance, WC or total hospital LOS was reported between these two weaning techniques in difficult-to wean patients,<sup>12</sup> although the application of a well-defined protocol, independent of the mode used, may result in better outcomes than uncontrolled clinical practice both in the ICU and in the RICU.<sup>12,15</sup>

An important component of the weaning protocols is availability of physiotherapy. It has been demonstrated that early physiotherapy results in benefits in critical patients in the ICU.<sup>31,36,37</sup> The ERS Task Force on the basis of these reports suggests that efforts to prevent or treat respiratory muscle weakness might have a role in reducing weaning failure.<sup>4</sup>

**Table 4** Causes of ICU admission of WC patients coming from ICUs outside Pisa.

Causes of ICU admission	n	%
COPD exacerbation	48	33.3
pneumonia/ARDS	17	11.8
cardiovascular disease	12	8.3
post-surgery	26	18.2
polytrauma	15	10.4
other	26	18.0
TOTAL	144	100



## Respiratory intermediate care units

In our model the RICU inside the acute care university-hospital worked also as "step down" for difficult-to wean patients with cost saving compared with ICU. This activity was not detrimental for management patients with ARF or ACRF with NIV. Indeed in the same period 95 patients suffering from ARF or ACRF were admitted to undergo NIV with a success, intubation and mortality rate of 82.2%, 14.7% and 3.1% respectively, a result in line with best reported NIV outcomes.<sup>2,3</sup>

## Costs

We confirm that RICU and WC may be cost-effective alternatives to acute ICUs in the management of difficult-to wean patients. Several observational studies estimate lower daily costs of care for ventilator-dependent patients in WC, primarily through reduced need of personnel, reduced costs for monitoring (e.g. non-invasive), technical equipment (e.g. portable ventilators), diagnostics and therapeutics.<sup>14,29,38,39</sup> The cost-benefit ratio of the program warrants prospective investigations.

## Limitation of the study

The study was retrospective, this initial experience involves a relatively small sample size, the available information regarding pre-morbid functional status and complications during the previous ICU stay is limited. Finally, the present study was conducted in Tuscany and may not be representative of other countries.

In **conclusion** the sequential activity of a RICU and a WC resulted in additive weaning success rate of difficult-to wean patients with reduced costs compared to ICU. The cost-benefit ratio of the program warrants prospective investigations.

## Conflict of interest

All authors declare to have no conflict of interest about the submitted paper.

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